



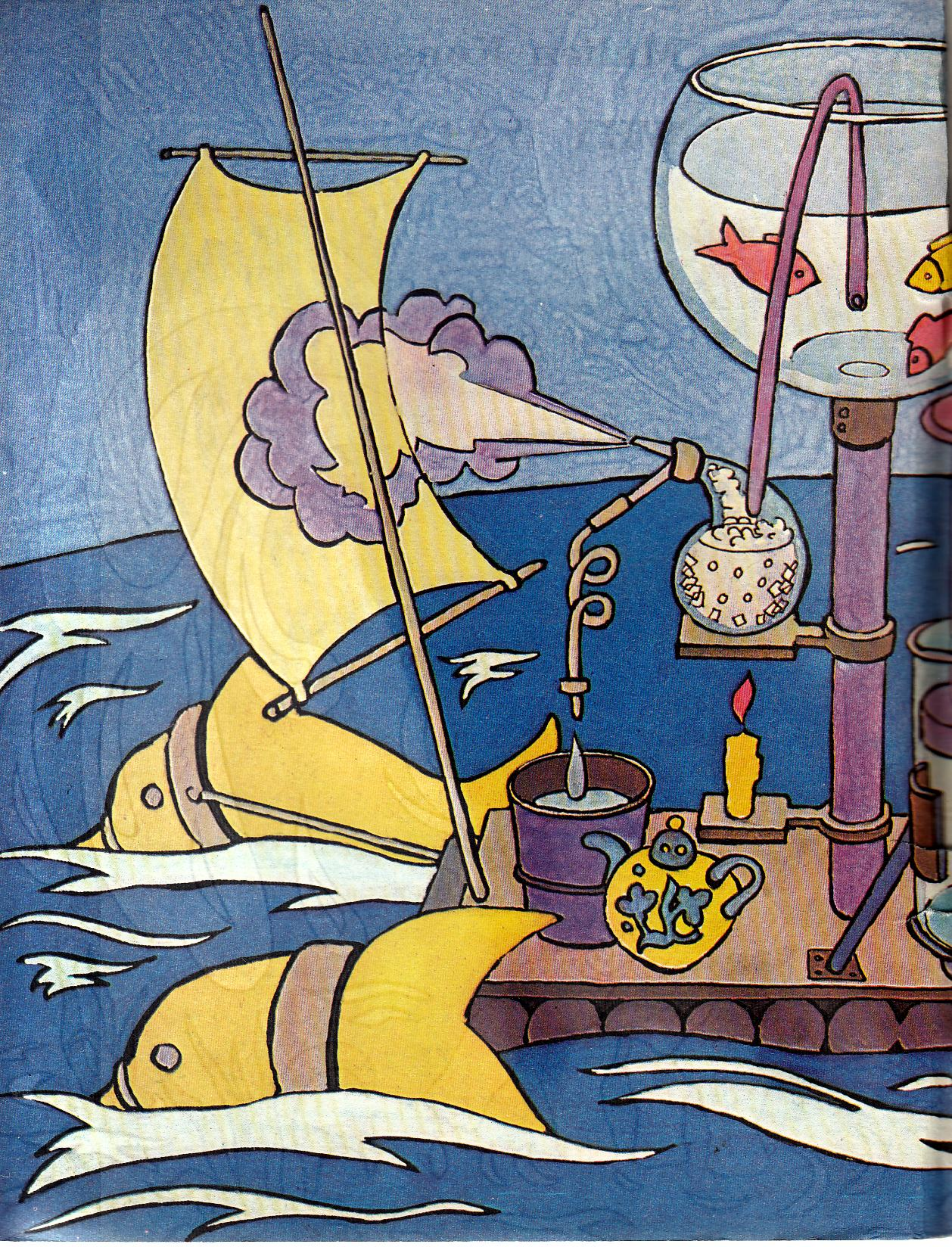
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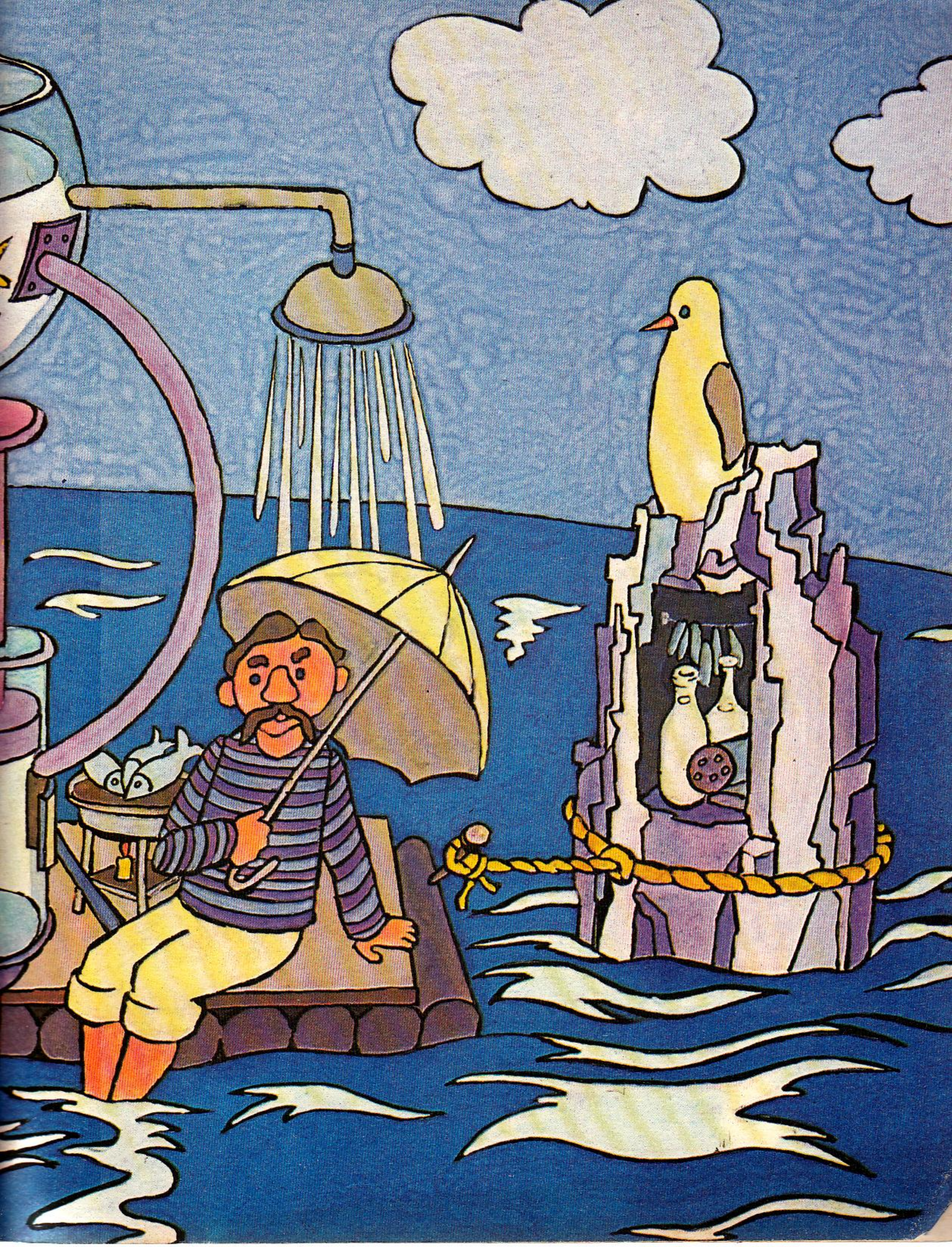
Mailen Konstantinovsky

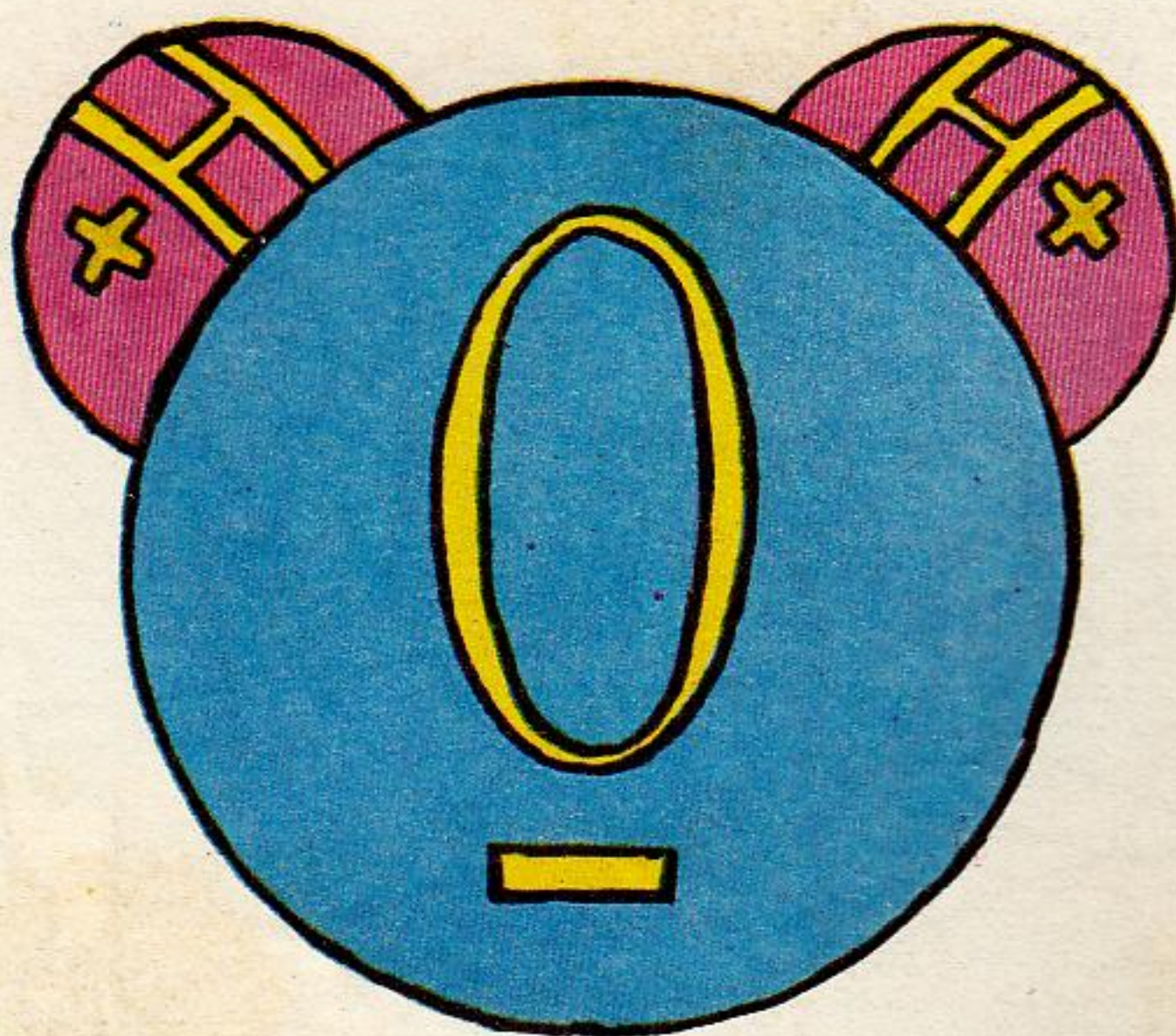
WHY WATER

IS WET









Mailen Konstantinovsky

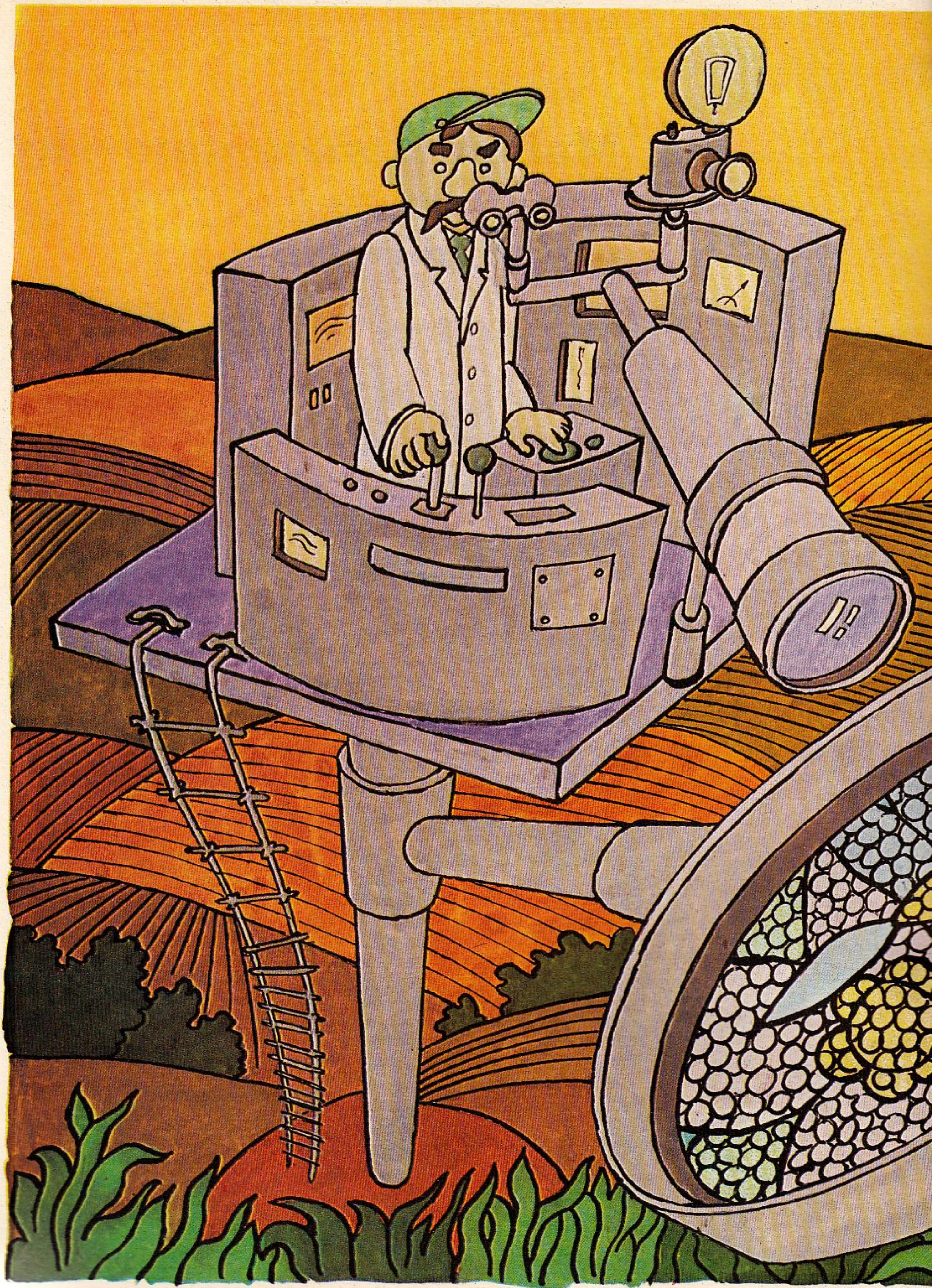
**WHY WATER
IS WET**

Translated by K. M. Cook-Horujy

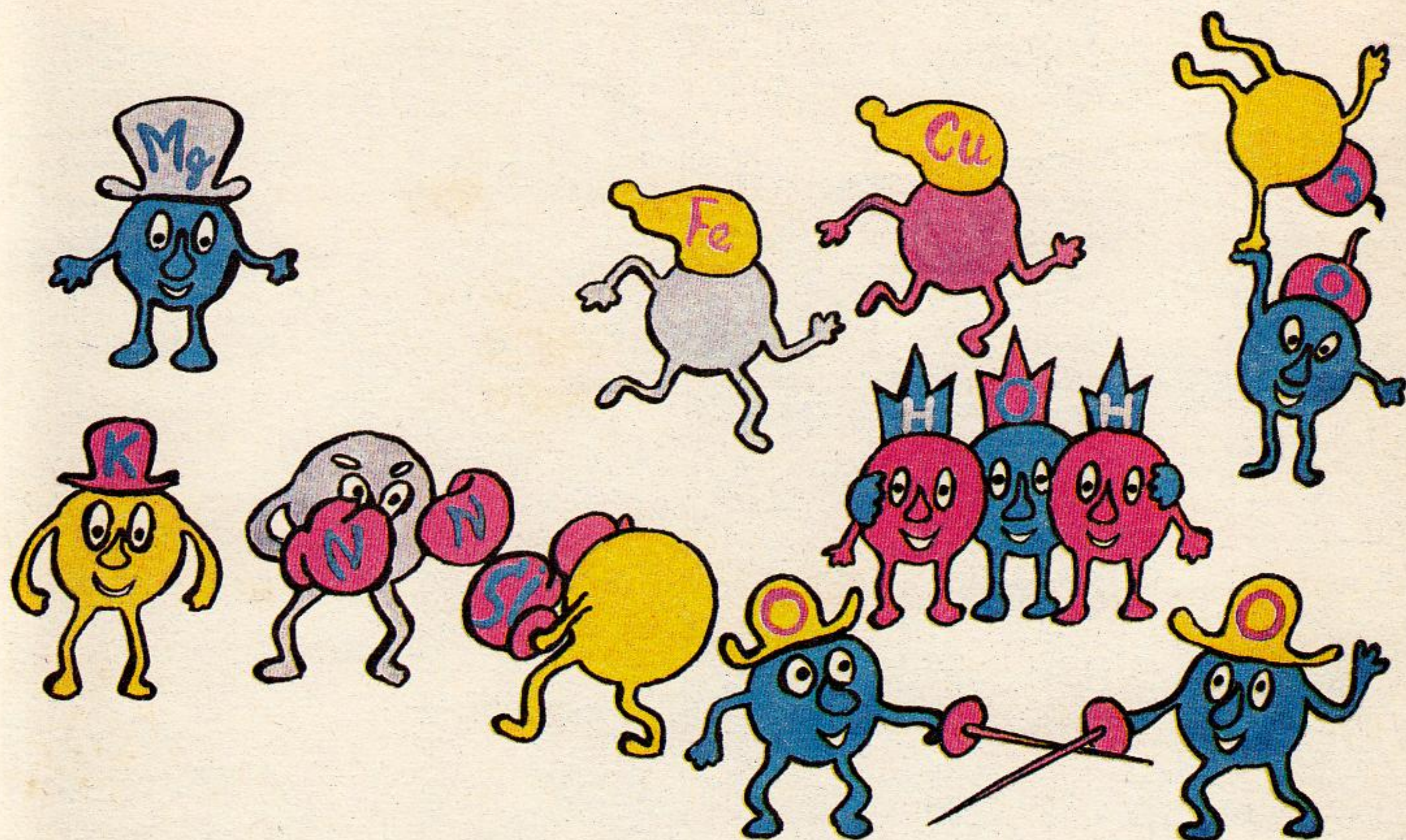
Drawings by Andrei Platonov



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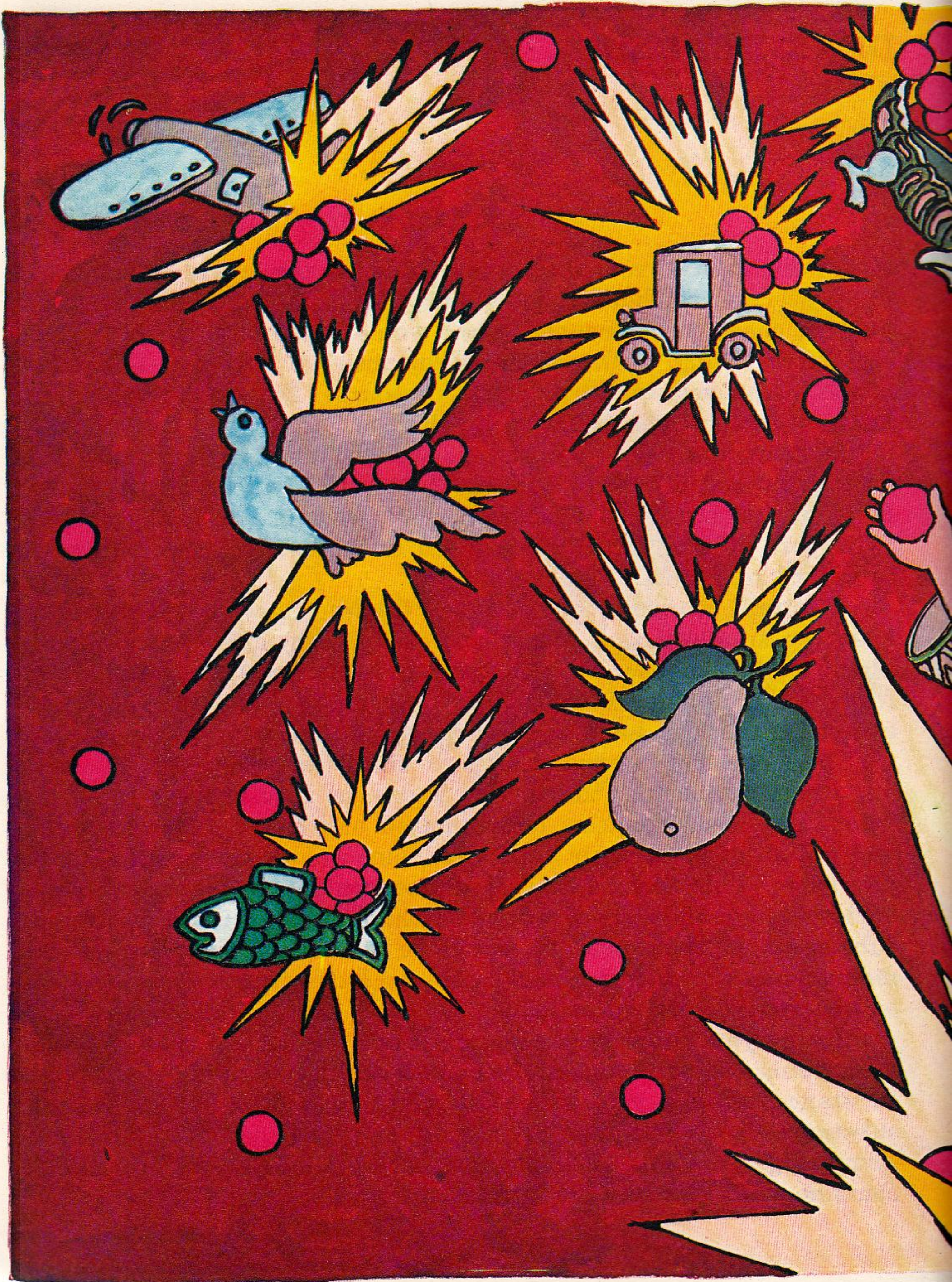
If I were to ask you what everything in the world is composed of—water, earth, houses, machines, plants and animals, and, last but not least, we ourselves, what would you reply? I think you'd say: "Everything in the world is composed of tiny particles called atoms." And you would be right, of course. But only partly right. Let me explain what I mean by that.

Imagine you ask me a question like: "What is the text of this book composed of?" And I reply: "Letters!" I will be right too, but also only partly right. And obviously you will add to my answer: "The text of this book is composed of words, and the words are composed of letters!"

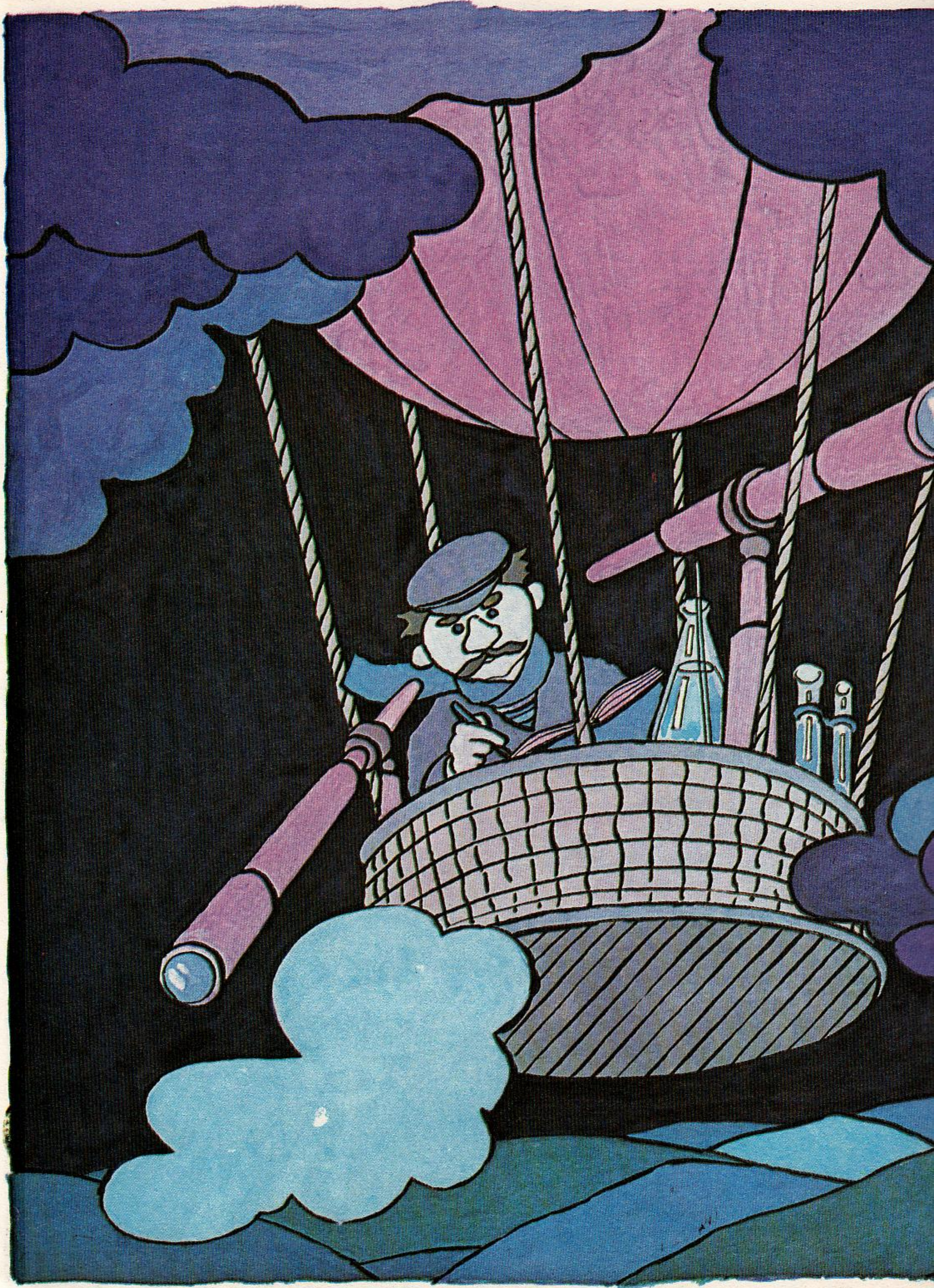
If letters could not be combined into words we could not write even the simplest book. There are only twenty-eight letters in the alphabet, but thousands upon thousands of words can be made up from them, and goodness knows how many books, songs, school essays and letters have been written with them!

There are more atoms of various kinds than there are letters in any alphabet, but not that many. Today, as I write these lines, the "atom alphabet" contains one hundred and seven different atoms and not all of them occur naturally. Some are created artificially by physicists. This means that if atoms could not combine to form various compounds, there would be only about a hundred different substances in the world. It would be a terribly poor, boring and monotonous world, like a book with one letter on the first page, one on the second, and so on...

But as you know very well, the world is not like that. Without even going out of the room, you could count thousands of different substances around you. All in all science knows of several million substances with different properties, and each day the number is increasing. This variety is possible only because atoms are able to combine with one another just as letters do.









10 HOW IDENTICAL ATOMS COMBINE

Have you seen many words consisting of one letter only? I'm not even sure whether we should use the term "words" for exclamations such as "oo", "aa" and "ee" and the like.

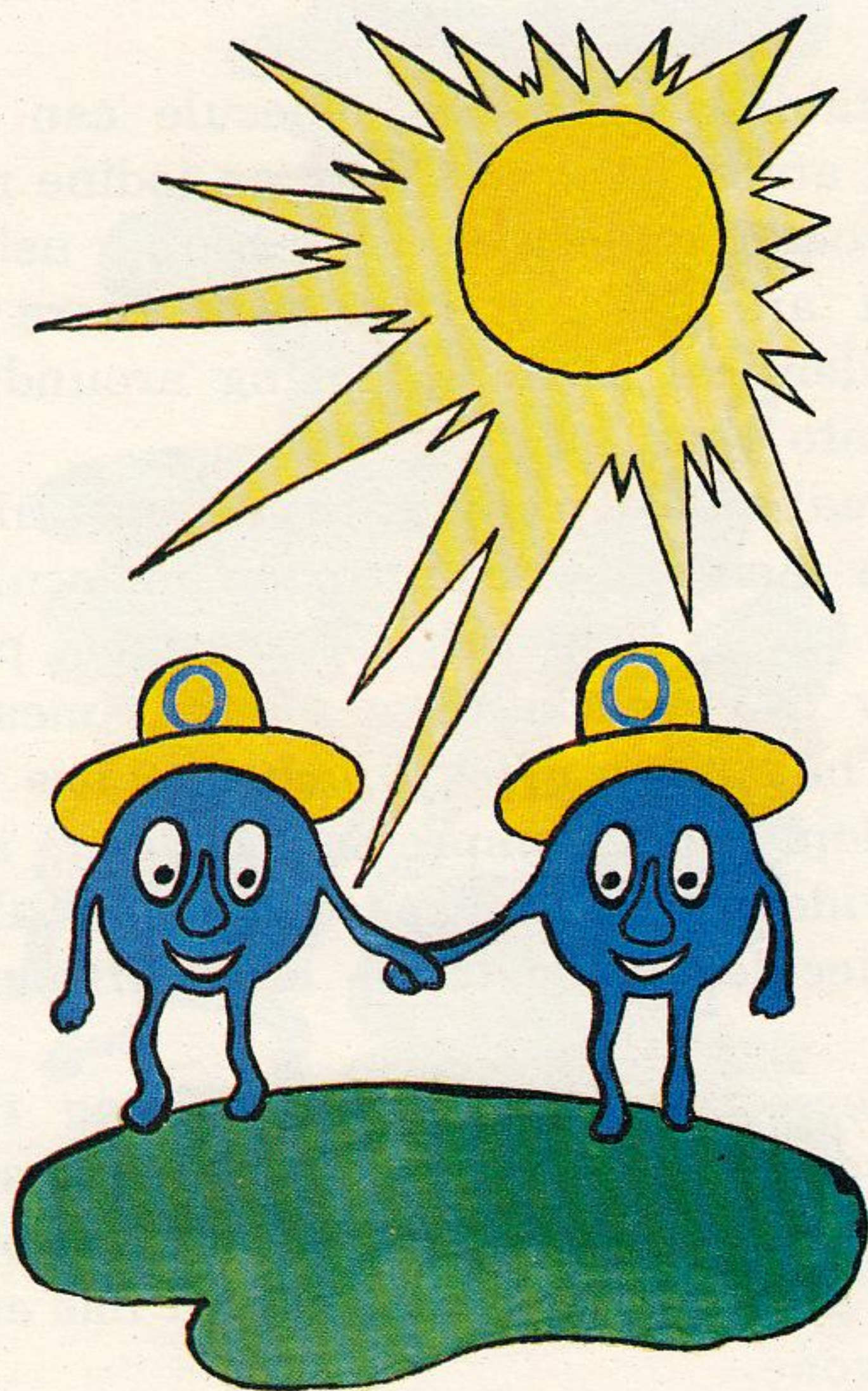
But what about atoms?

Let us take, for example, a piece of a substance which you know well, iodine. The brown liquid sometimes applied to cuts is not pure iodine, but a solution of iodine in spirit. In a chemist shop you might see pure iodine as well, greyish-black crystals with a violet lustre. These crystals contain iodine atoms only, no other atoms at all. If you are shown one of these crystals and asked: "What is the smallest particle of this substance?", don't be in too much of a hurry to reply: "An iodine atom, of course, what else?" Because each iodine atom in a crystal is bonded to another iodine atom. These paired atoms do not break up, even when the crystal melts or evaporates.

If we did somehow manage to break up these pairs, what substance would the individual atoms of iodine constitute?

You might think this wouldn't make any difference, because the atoms are still the same. But it would be a

substance with completely different properties. So one atom and two of the same atoms bonded together are not the same thing.



Now you know what to say if anyone shows you an iodine crystal and asks you the tricky question:

12 "What is the smallest particle of this substance?" The correct answer is: "Two iodine atoms bonded into a pair."

If you want to reply to that question not only correctly, but also in a scientific way, you must take the iodine crystal and say: "The smallest particle of this substance is a molecule composed of two atoms of iodine."

So we have established that a molecule can consist of two completely identical atoms. And not only an iodine molecule. There are lots more diatomic molecules all around us! At this very moment while you are reading this book there are molecules consisting of two identical atoms whizzing around you and even flying inside you, into your lungs.

You will have realised, of course, that I am talking about air molecules, or, to be more precise, nitrogen molecules and oxygen molecules, of which air is composed for the most part.

When people say "we breathe oxygen", they mean molecules of two oxygen atoms. The oxygen mask which they use for seriously ill people, steel cylinders with compressed oxygen, and the liquid oxygen which provides fuel for space rockets all contain the same diatomic molecules. Are there any different ones? Yes, there are.

During a thunderstorm molecules containing three atoms of oxygen form in the air, and people say: "There's a smell of ozone." The gas composed of triatomic oxygen molecules is so different from the gas composed of diatomic molecules that it has even been given a different name: ozone.

Oxygen has no smell, but ozone has a very strong smell (the word is derived from the Greek word for "to smell").

Oxygen is colourless and invisible. Ozone is visible. It is a bluish gas.

We breathe oxygen, but we must not breathe ozone. True, a small amount of ozone makes the air smell fresh, but in large quantities ozone is highly poisonous.

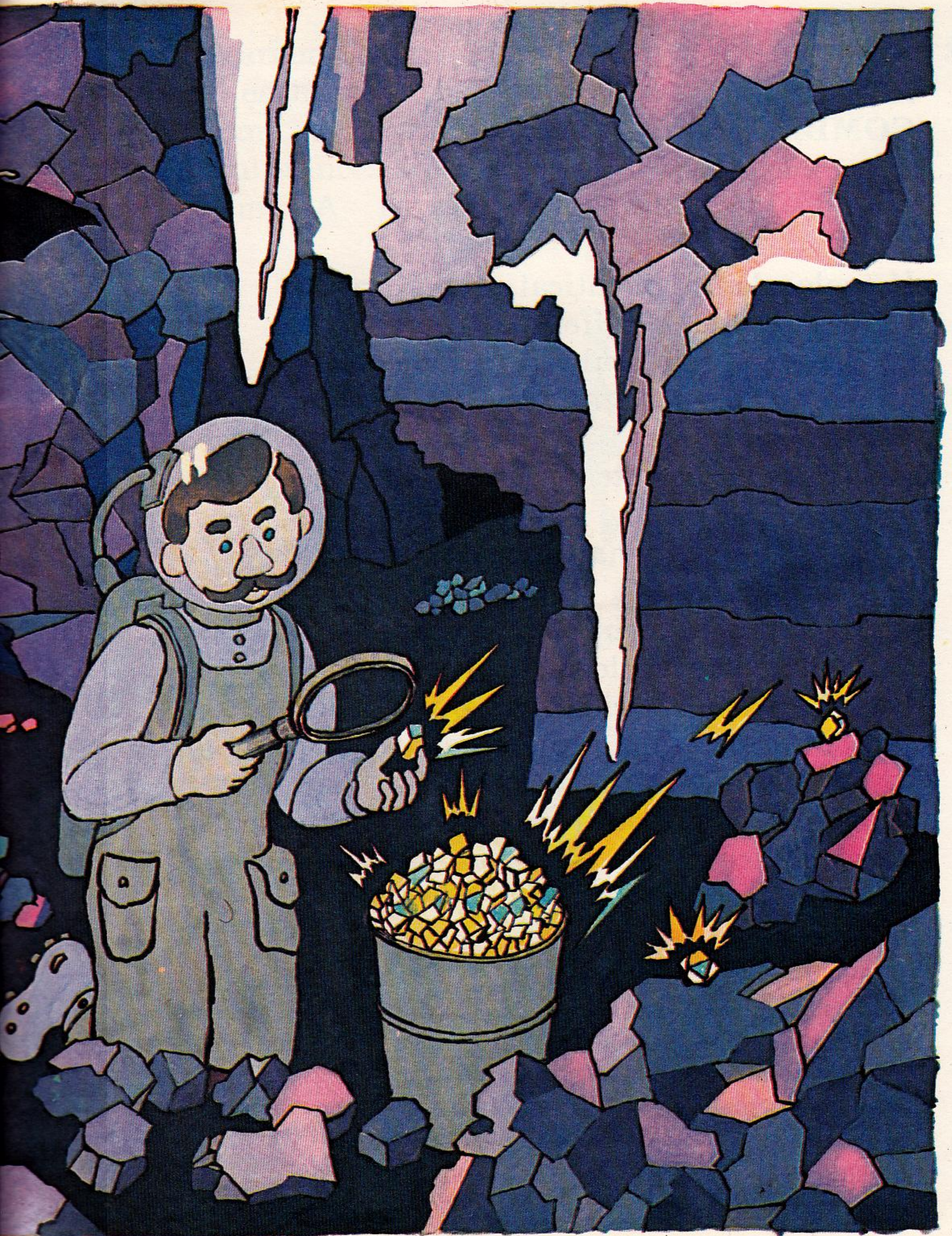
Ozone is 50 per cent heavier than oxygen.

Liquid oxygen is light blue, whereas liquid ozone is dark violet. And the two liquids boil at different temperatures.



It is hard to believe that the molecules of these two substances are composed of completely identical atoms. Strange, but true, as the saying goes.





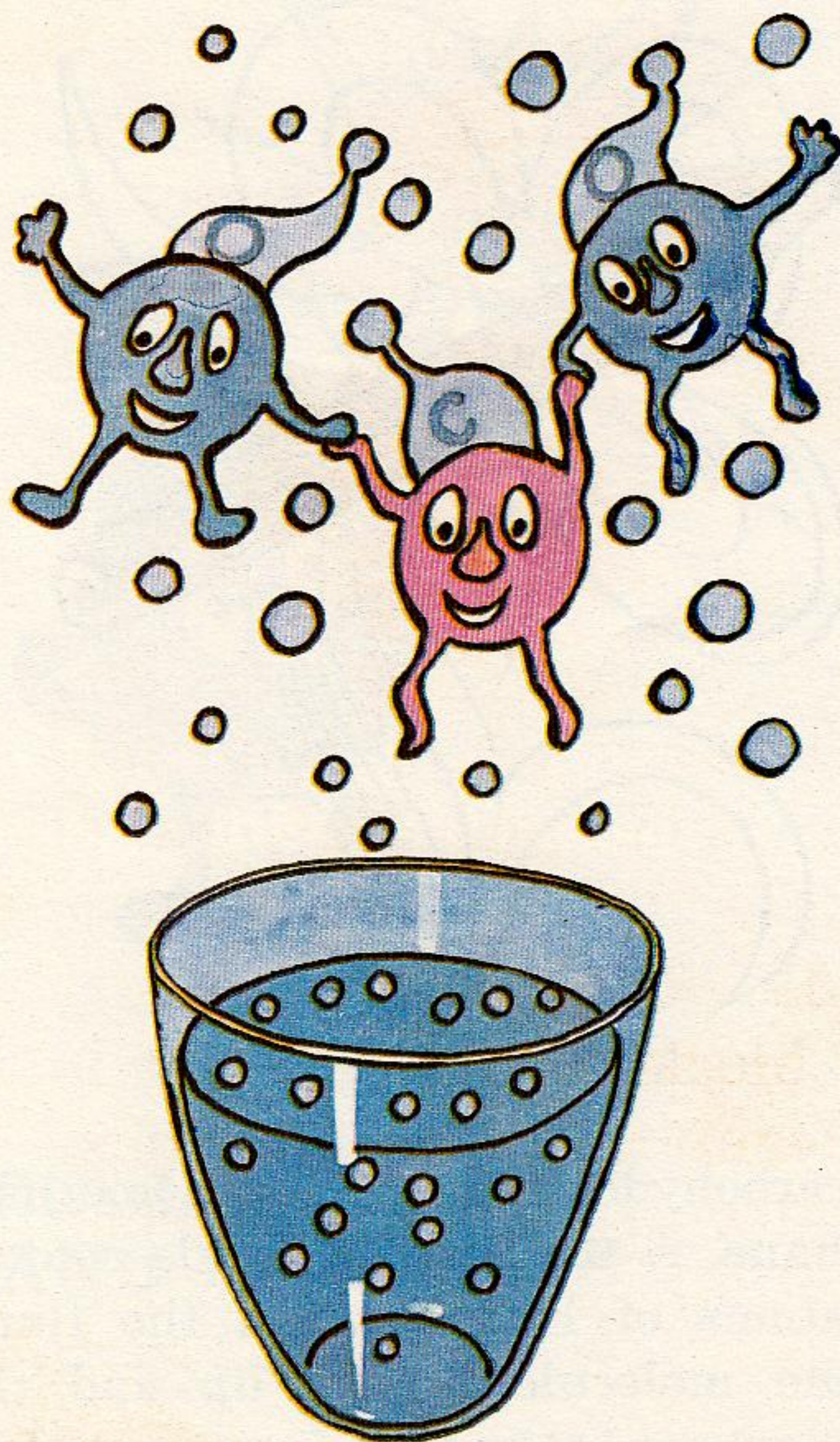
16 HOW DIFFERENT ATOMS COMBINE

If molecules of identical atoms are so different, what a difference there must be between molecules of unidentical atoms. Let's take a look at the air again. Shall we find some of these molecules there too? Of course we shall.

Do you know what sort of molecules you breathe out? (Not just you, of course, but all human beings and animals.) The molecules of your old friend carbonic acid gas. Bubbles of carbonic acid gas prick your tongue when you drink soda water or fizzy lemonade. The blocks of dry ice put in boxes of ice-cream also contain these molecules, for dry ice is solid carbon dioxide.

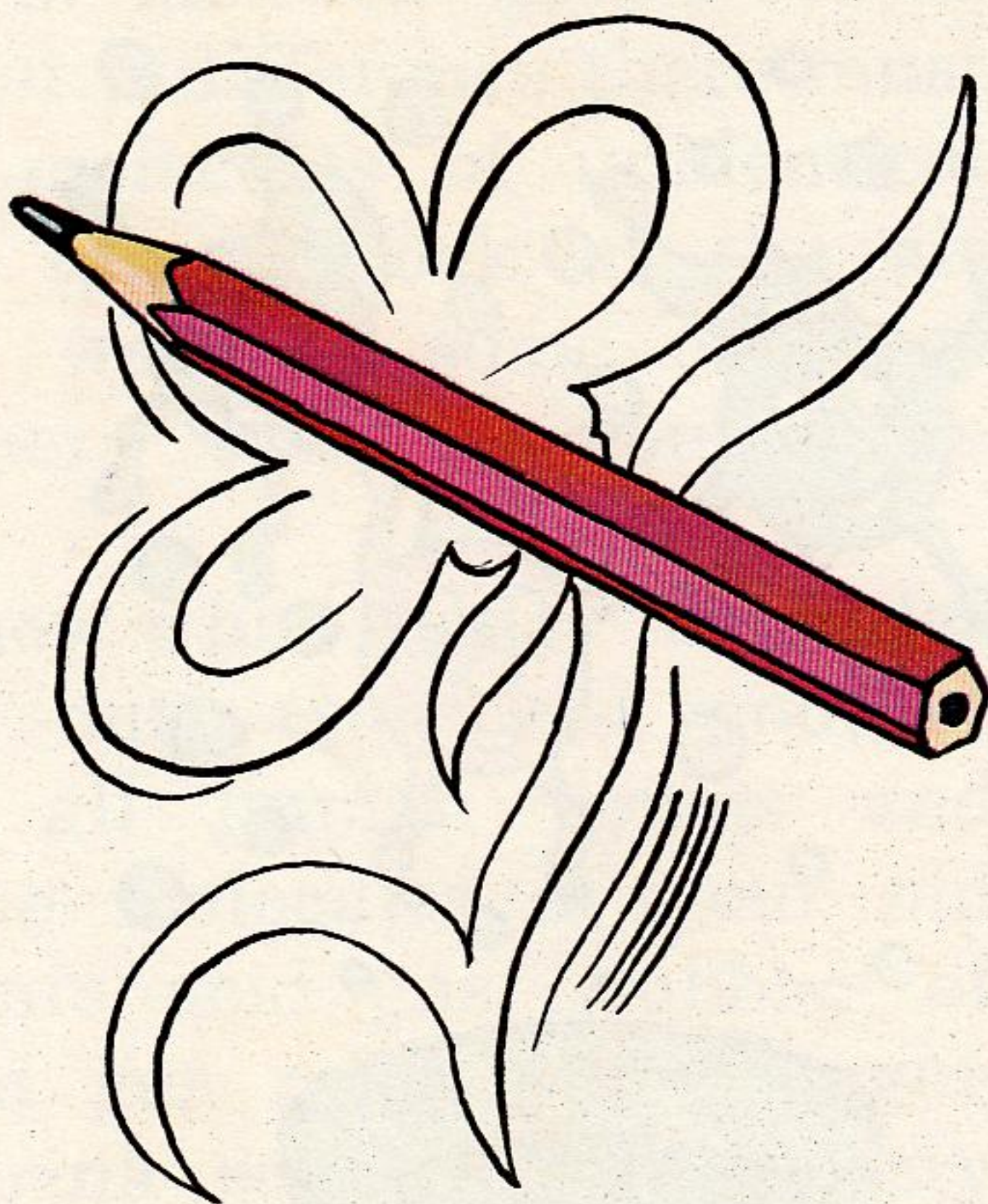
A molecule of carbonic acid gas contains two atoms of oxygen with one atom of carbon in the middle. When you write with an ordinary pencil, some tiny flecks of graphite are left on the paper. They are composed of carbon atoms too. And carbon atoms also "make up" diamonds and ordinary soot. Again we have the same atoms and quite different substances.

When carbon atoms combine not only with each other but with other "alien" atoms, this produces so many different substances that it is hard to count them. A particularly large



number of substances is produced when carbon atoms combine with atoms of the lightest of all gases, hydrogen. All

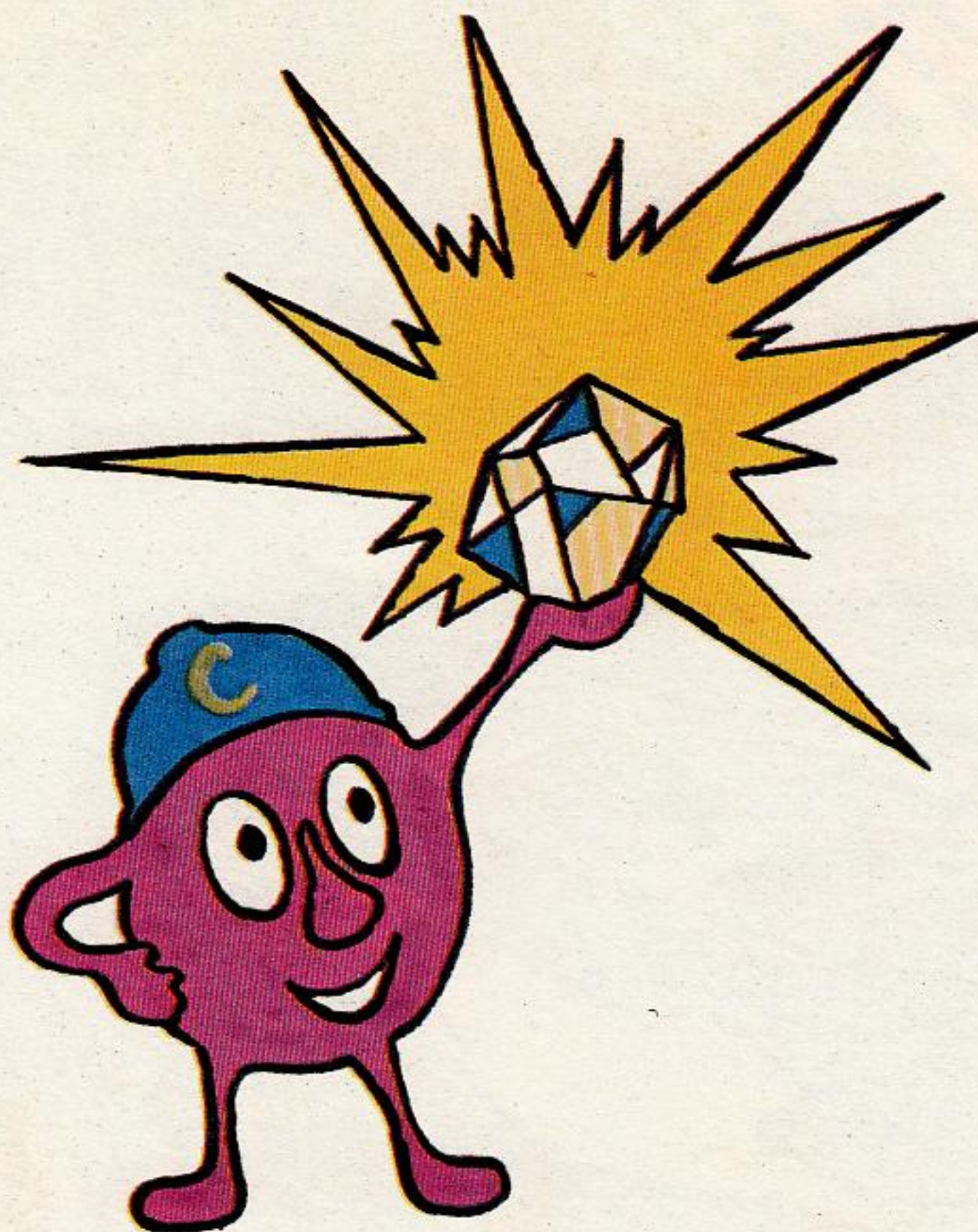
18 these substances are called carbohydrates, but each carbohydrate has its own name.



The simplest carbohydrate is a gas sometimes used in the kitchen stove, methane. A methane molecule contains one atom of carbon and four atoms of hydrogen. In the flame of the stove burner the methane molecule breaks up and the carbon atom combines with two oxygen atoms to form a molecule of carbonic acid gas or carbon dioxide. Hydrogen atoms also combine with oxygen atoms to form molecules of the most important and vital substance in the world!

The molecules of this substance are also to be found in large numbers in the air. To a certain extent you play a part in this,

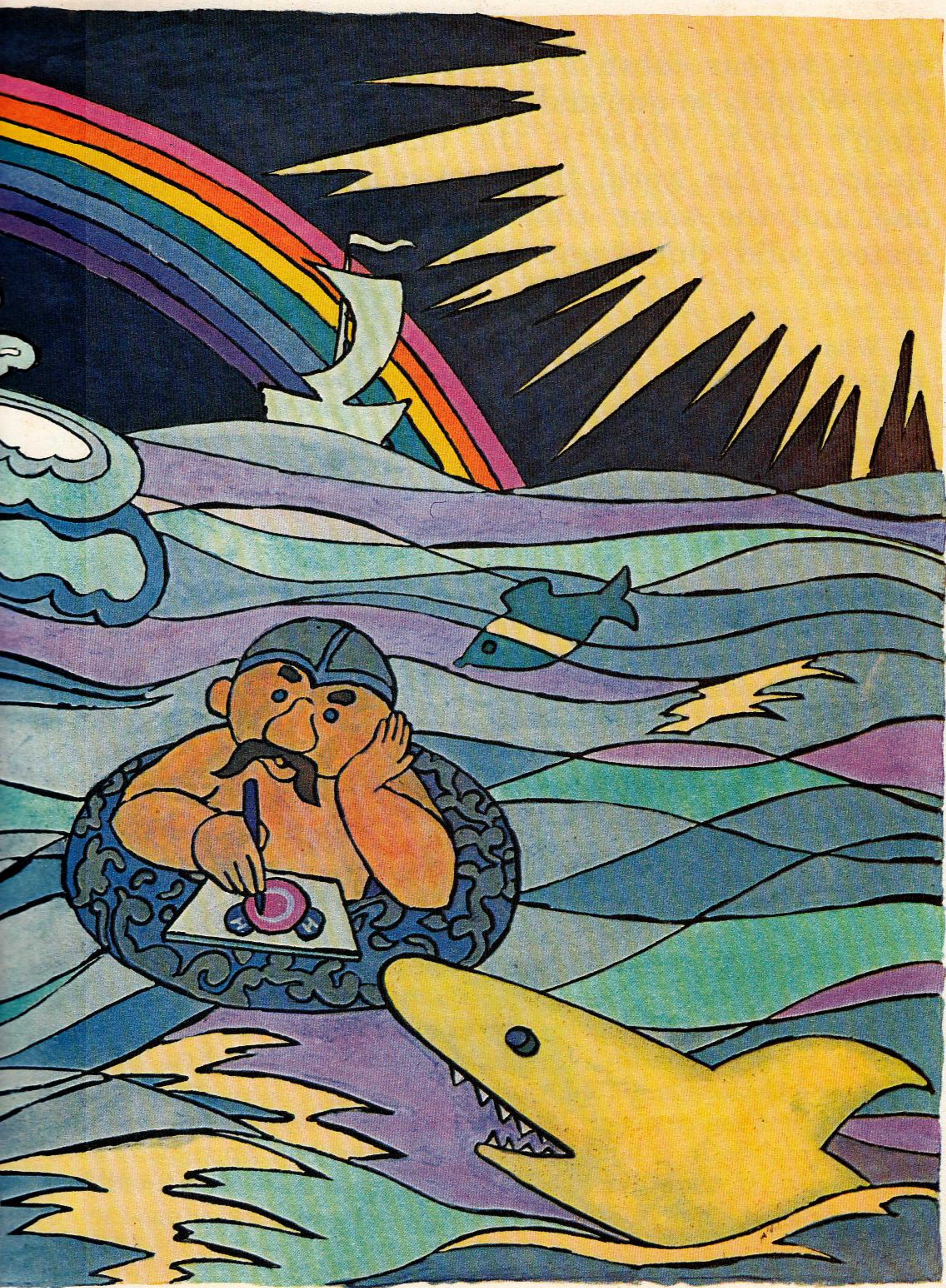
because you breathe out these molecules into the air together with molecules of carbonic acid gas. What substance is this? If you haven't guessed, breathe onto a piece of cold glass and you will see it in front of you—water! 19



HOW MOLECULES COMBINE AND SEPARATE

You may have seen one of the most remarkable properties of water in winter on a river, lake or pond in the form of ice, which is solid water. Under the ice is liquid water. Over the ice is





22 water vapour (always present in the air). What is so unusual about all that? Here's what. Water is the only substance in the world that can exist at one and the same time in all three states: solid, liquid and gaseous.

What exactly are these three states of a substance? In what respects are they different and in what respects are they similar?

Let us first examine a substance in the solid state. As you know in order to break something, you have to use force, sometimes quite a lot of force. So we can make our first deduction: the molecules from which a solid is composed are firmly combined. Otherwise everything we call a solid would have disintegrated long ago.

You also know that a solid, until it is melted or broken, retains the shape of a plate, a cube, a pipe, a ball, and so on. In other words, all solids retain their shape. So we can make our second deduction. In a solid there is a fixed arrangement: each molecule has its own place, like soldiers in formation (the formation retains its shape as long as the soldiers stay in their places).

Finally, you also know about this property: a solid is very hard to compress. What does this indicate? That in a solid the molecules are "packed" together very tightly, as tightly as seeds in a sunflower.

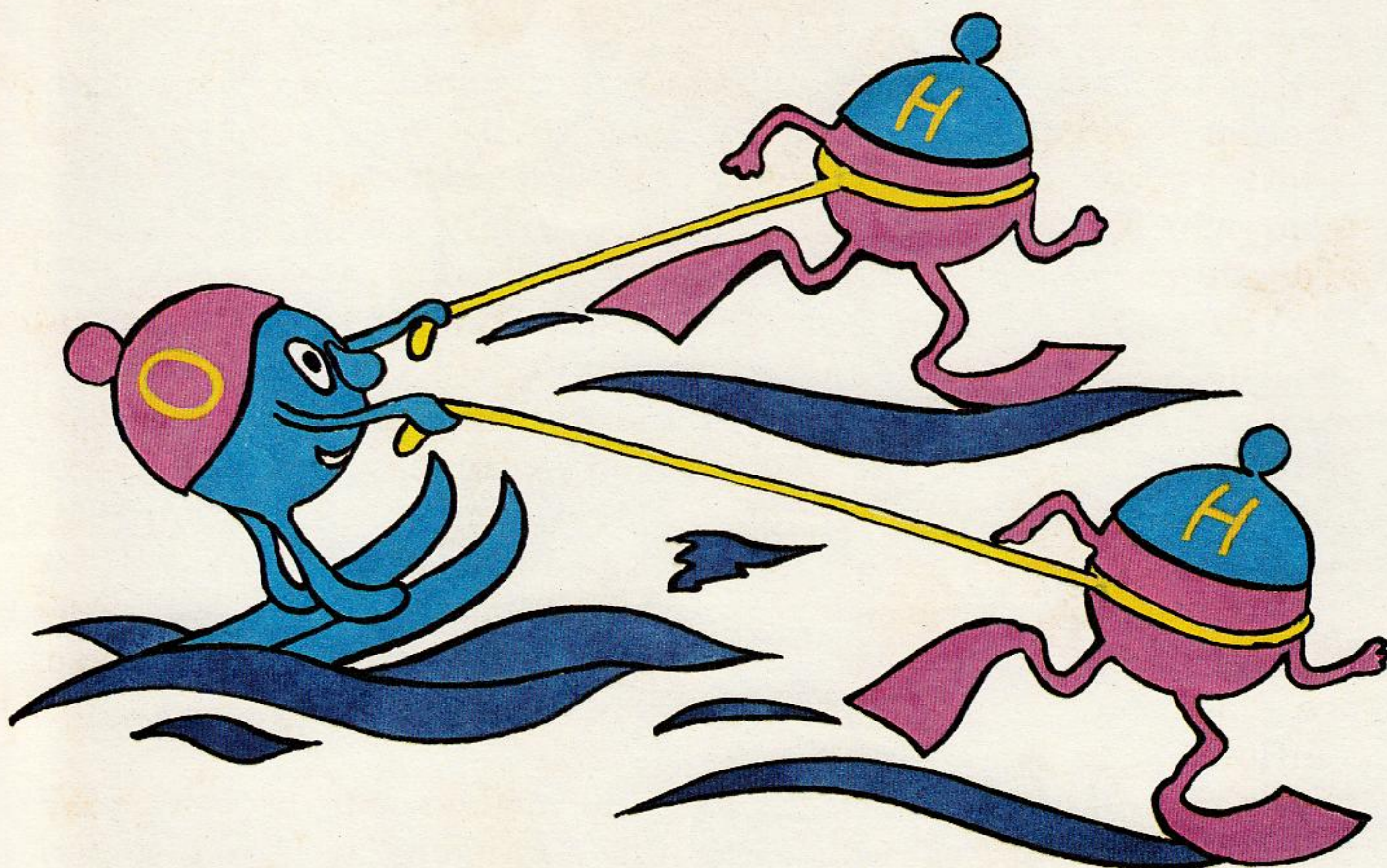
The same sunflower seeds, only in a glass, can be compared to the molecules of a liquid. Here the arrangement is not so strict, although they are also "packed" tightly. So a liquid is hard to compress too. You can see this if you draw water into a syringe, block the opening for the needle, then try to squeeze the plunger. So in a liquid the molecules are also tightly packed.

But are the molecules in a liquid firmly bonded? You wouldn't think so, because a liquid can break up into tiny droplets. But imagine how many molecules there are in a tiny droplet. Billiards of milliards! So in a liquid too the molecules hold on tight to their neighbours. If they did not, the liquid would break up not into drops, but into individual molecules.

So we have now established that liquids and solids have something in common: the molecules in them are tightly packed, that is, arranged close to one another, and the molecules hold on tight to their neighbours.

But there is also an important difference. Because the molecules in a liquid are not so strictly arranged as those in a solid, a liquid does not retain its shape. To put it simply, it flows.

Now let us compare a liquid with a gas. If you have ever pumped up a bicycle tyre, you will probably have noticed that air,



unlike a liquid, can easily be compressed. A litre of air, if well pressed, can be condensed into the space of a thimble! You will realise, of course, why this is possible. Because there is space between air molecules. In your room, for example, the distance between two neighbouring air molecules is about ten times greater than the size of the molecules themselves.

Let us now compare a liquid and a gas in another respect. You have bought a half-litre packet of milk. You pour the milk into a





26 bottle and it still takes up half a litre. In a jar, saucepan, or coffee-pot, everywhere milk takes up the same volume.

But what about a gas? It does not have a definite volume. The gas molecules scatter all over the place at the slightest opportunity, when they are not prevented from doing so by the walls of a vessel or a room. If you were to open a gas cylinder in space, the gas molecules would scatter all over the universe!



From this you will immediately make the following deduction: nothing holds gas molecules next to one another.

Let us now sum up. In solids and in liquids the molecules are arranged close to each other and firmly bound together. In gases the molecules are a long way from one another and they are not bound together. Now you can make another important deduction. The force which helps molecules "hold on tight" to one another (physicists call this force **MOLECULAR COHESION**), operates only at short distances.

You may have wondered how a lizard manages to crawl along smooth walls, even ceilings, without falling down. What keeps it up?

On its fingers and toes it has tiny brushes consisting of millions of microscopic hairs. They penetrate into the minute cracks which even the smoothest surfaces have. In so doing the hair molecules get so close to the molecules of which the surface is composed, that molecular cohesion comes into action.

So a lizard is kept on a wall or ceiling not by suckers, as many people think, but by molecular cohesion.

But don't gas molecules ever get close to one another? I should say they do! They are continually flying into one another. In your room, for example, each air molecule has no less than about four milliard collisions each second!

Surely with such a large number of collisions air molecules should eventually all get close together and "hold on tight" to one another, combine in drops and crystals. Why don't they form clouds and mists or fall on the earth as rain, like water molecules do? Why are there no little streams of liquid oxygen, no morning dewdrops of liquid nitrogen, no frost and glaciers of solid carbonic acid? What prevents the molecules of these gases from combining when they get close?

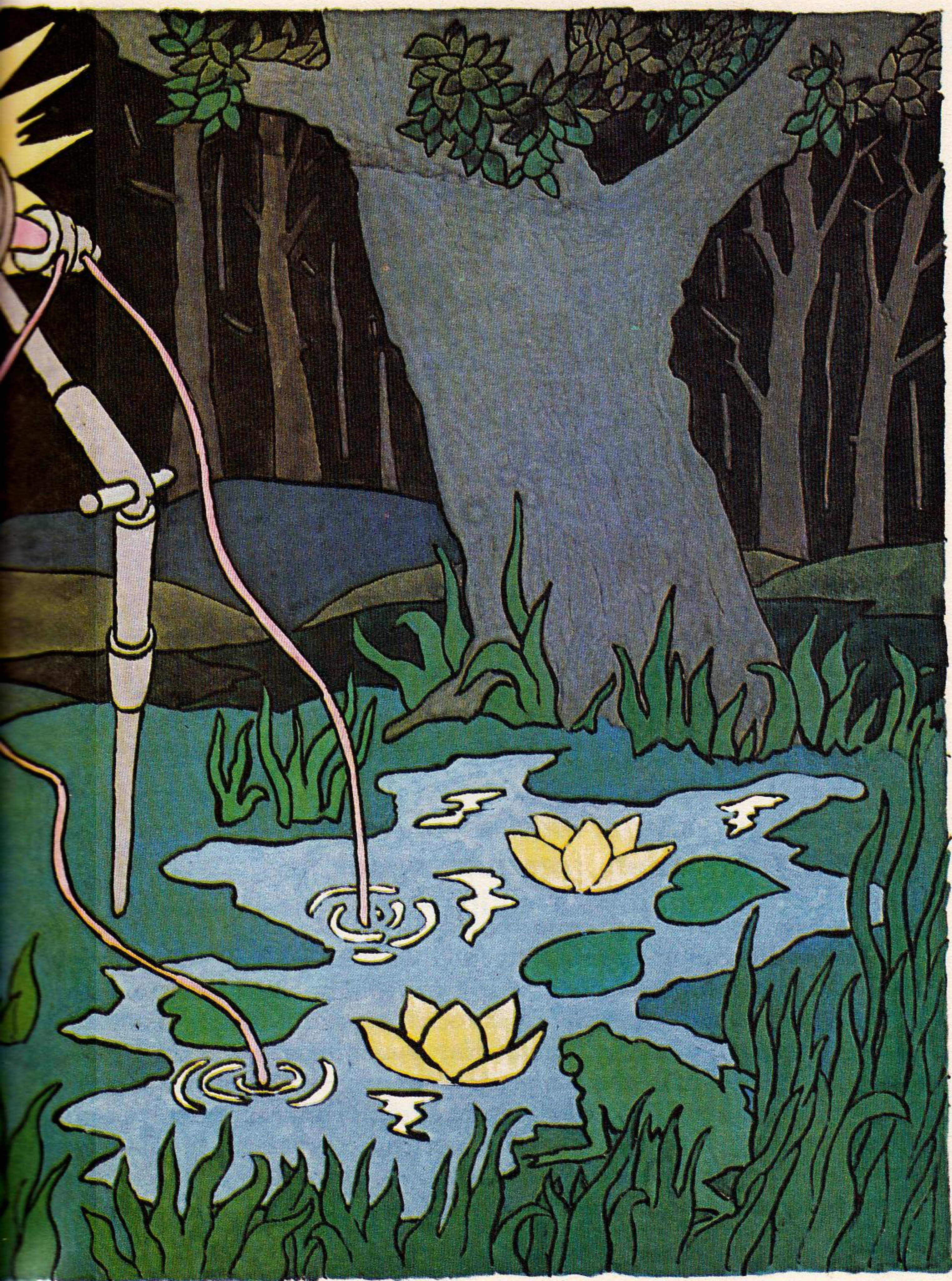
The answer is speed. The molecules of oxygen and nitrogen in your room are moving at a speed of about half a kilometre per second, which is 1,800 km per hour, 50 per cent higher than the speed of sound! (And remember that this is their average speed: there are slower and faster molecules.)

When they collide at this high speed, the molecules do not have time to get bonded. They just bounce off one another like billiard balls.

Now you know how to help gas molecules combine: you must reduce their speed. But how? By cooling the gas. Because the higher the temperature, the faster the molecules move. And, conversely, the lower the temperature, the slower the molecules move. So any gas can be cooled to such an extent that it will turn into a liquid or even into a solid.

However, although the movement of the molecules slows down, it does not stop. Of course, the molecules in a solid or a liquid do not fly about as they do in a gas. In a solid they "dance on one spot". Whereas in a liquid the molecules dance on one spot for a





30 while then, hop! And they are dancing on another spot. In a while they hop to a third, and so on.

The most energetic molecules can hop so far that they land on the surface, separate from their neighbours and fly off. The liquid evaporates. And if it is heated to boiling point, the molecules begin to separate not only on the surface, but also inside the liquid until it has all turned into steam (or we could say "into gas" which is the same thing).

HOW WATER MOLECULES COMBINE WITH ONE ANOTHER

The strange thing is that oxygen molecules begin to combine into drops at a temperature of 183 degrees below freezing point, nitrogen molecules at 196 degrees below freezing point, and water vapour molecules at 100 degrees ABOVE freezing point. At nought degrees, when oxygen and nitrogen are still very far from freezing, water is already turning into a solid—ice!

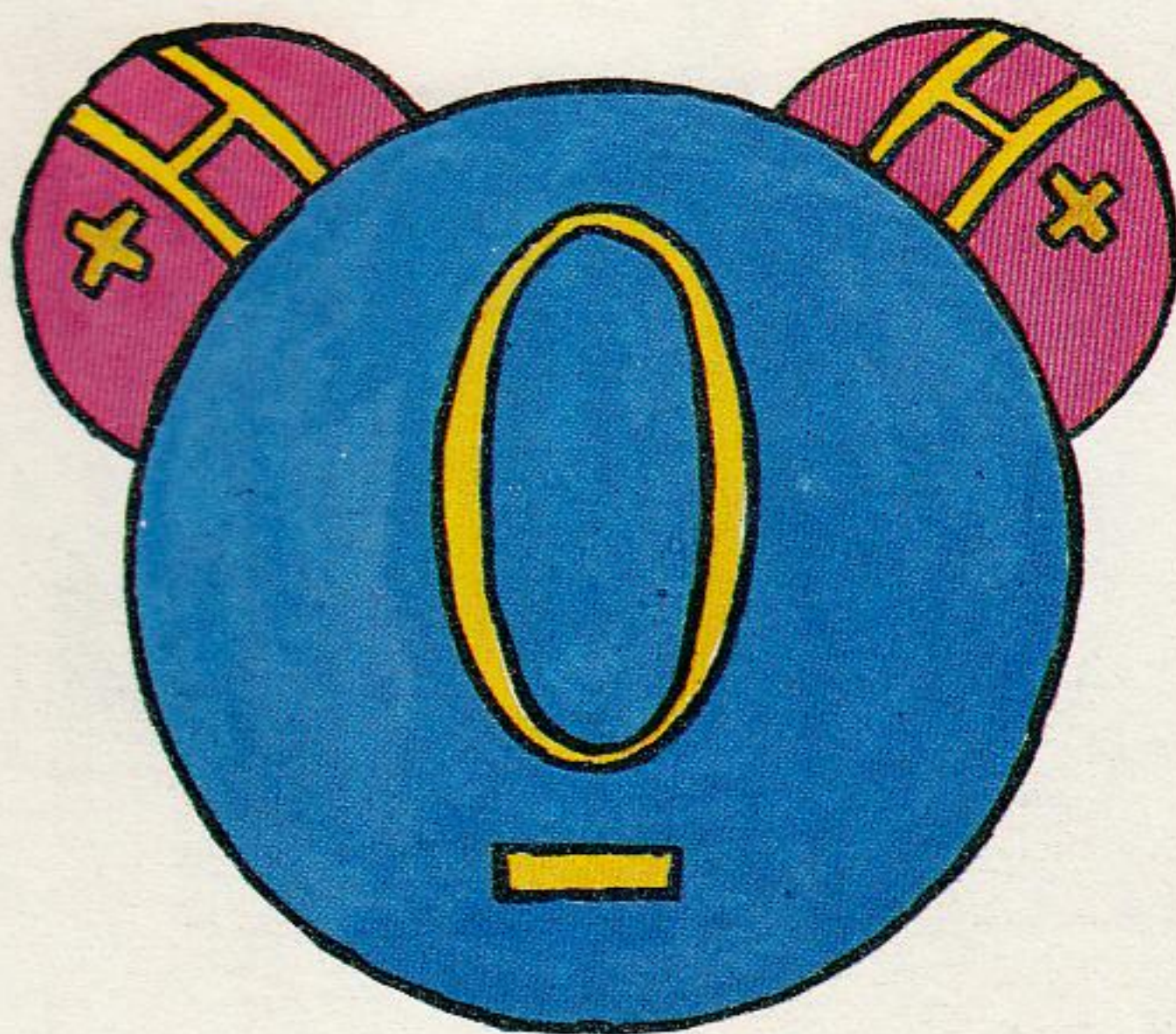
Why is this? Perhaps water vapour molecules move more slowly than their neighbours in the air—molecules of oxygen, nitrogen and carbonic acid gas? No, quite the opposite! Water molecules move faster, not slower, because they are almost twice as light as both oxygen and nitrogen molecules, to say nothing of molecules of carbonic acid gas. But wait a minute! If oxygen, nitrogen and carbonic acid gas remain gases in natural conditions, the water on the earth should have turned into a gas long ago. But you and I know that this is not the case.

So some force must help water molecules to combine in drops and crystals, in spite of the tremendous speed at which they collide. Thanks to this force water molecules when they collide do not behave like billiard balls, but like burdock. As soon as they touch one another, they stick together, and once they have stuck together you have to shake them very hard indeed to make them fall apart.

What exactly is this force?

Remember you and I thought that the two hydrogen atoms in a water molecule might have something to do with the molecule's unusual properties? Well, we were right.

Both of these hydrogen atoms could be marked with the plus sign (+) seen on one side of a torch battery. And the opposite side

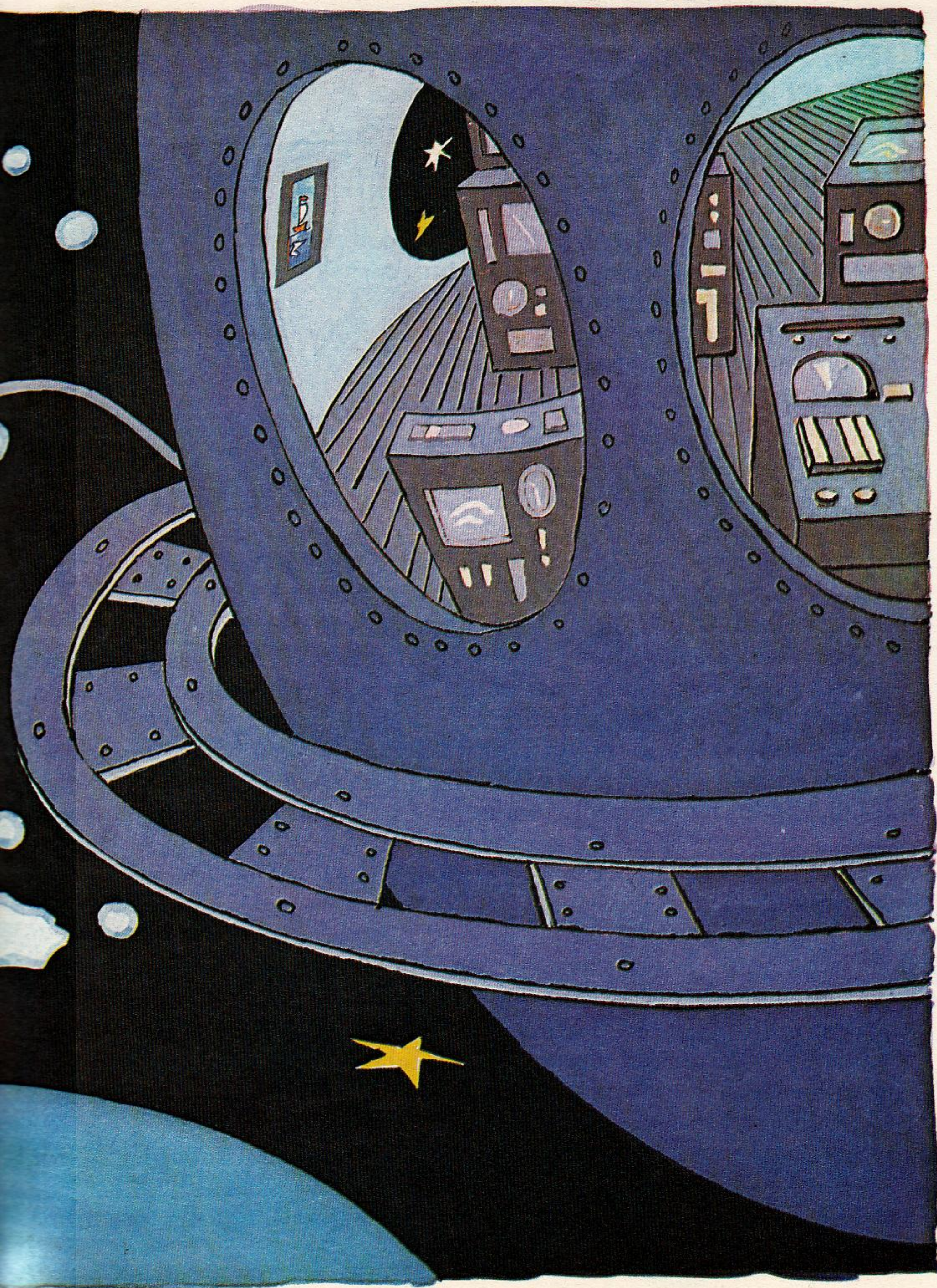


of the water molecule—with the minus sign (–) seen on the other side of the battery. Because a water molecule is an electrical particle! You can easily see how well electrical particles join together, by running a plastic comb over dry hair then putting it on some pieces of paper. The paper sticks to it at once.

The electrical force which helps to combine water molecules holds them together much more tightly than ordinary molecular cohesion.

If it were not for this electrical force there would be no ice, no rivers and no oceans, because water would be a gas!





34 HOW WATER MOLECULES COMBINE WITH "ALIEN" MOLECULES

Take some water into a pipette and look at it carefully. You will see that the surface is not flat, but curves up at the edges. The water by the glass has risen higher than in the middle. (In a jar and any other glass vessel water rises up at the edges too, but this is more noticeable in a pipette.)

What makes it rise?

You have probably guessed. Although the water molecules combine together very strongly, they combine even more strongly with the surface of the glass. In other words, the glass is **WETTED** by the water.

In that case why doesn't the water rise even higher up the glass? Weight prevents it from rising. Molecular cohesion pulls the water molecules up, but gravity pulls them down.

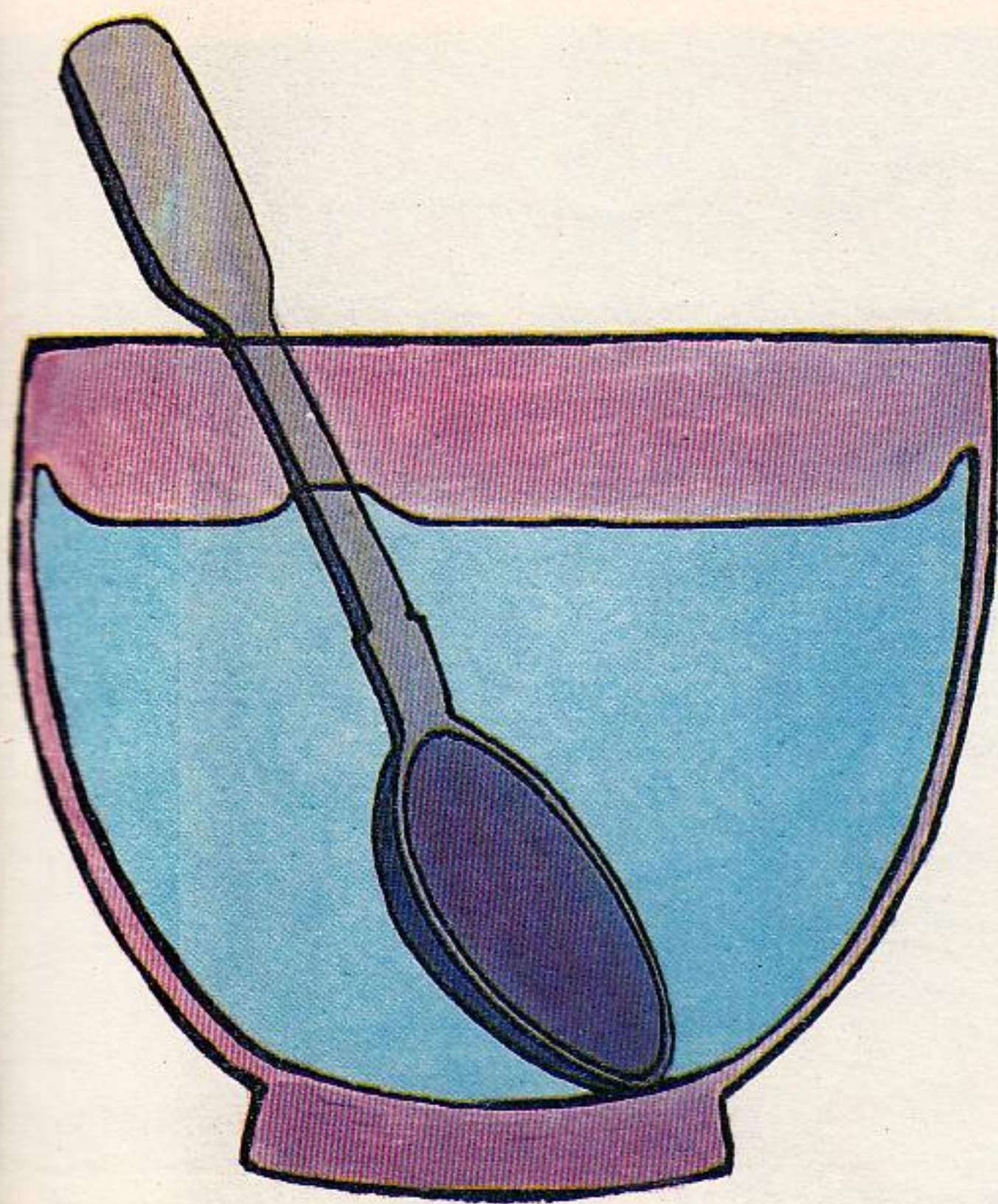
Apart from glass there are several other substances which are wetted by water, such as china, metals and many minerals, particularly chalk and gypsum...

Are there substances with which water molecules combine more weakly than to one another? I should say so! Sulphur, graphite, wax, paraffin, naphthalene, polyethylene and all fats. None of these substances are *wetted* by water.

Now imagine that you have been asked to design a drinking water tank for a spaceship. What material would you choose for it? One that is wetted by water or one that is not?

There is no gravity in a spaceship, so the water cannot spill. What about molecular cohesion? It remains there as usual, as if nothing had happened! I don't really need to say all this. You can see for yourself that if there were no cohesion between molecules in space, spacecraft and everything inside them would break up into individual molecules when launched into space.

Say you made the water tank out of a material to which water molecules adhere more strongly than to one another, glass, for example. What would happen then? The water would not rest until



it had wetted the whole inside surface of the tank and covered it with a level layer of water. What is more, if you turned the tap on, part of the water would come out of the tank, spread over its sides and cover the whole outside of the container as well. So instead of having water inside the container, you would have the container inside the water.

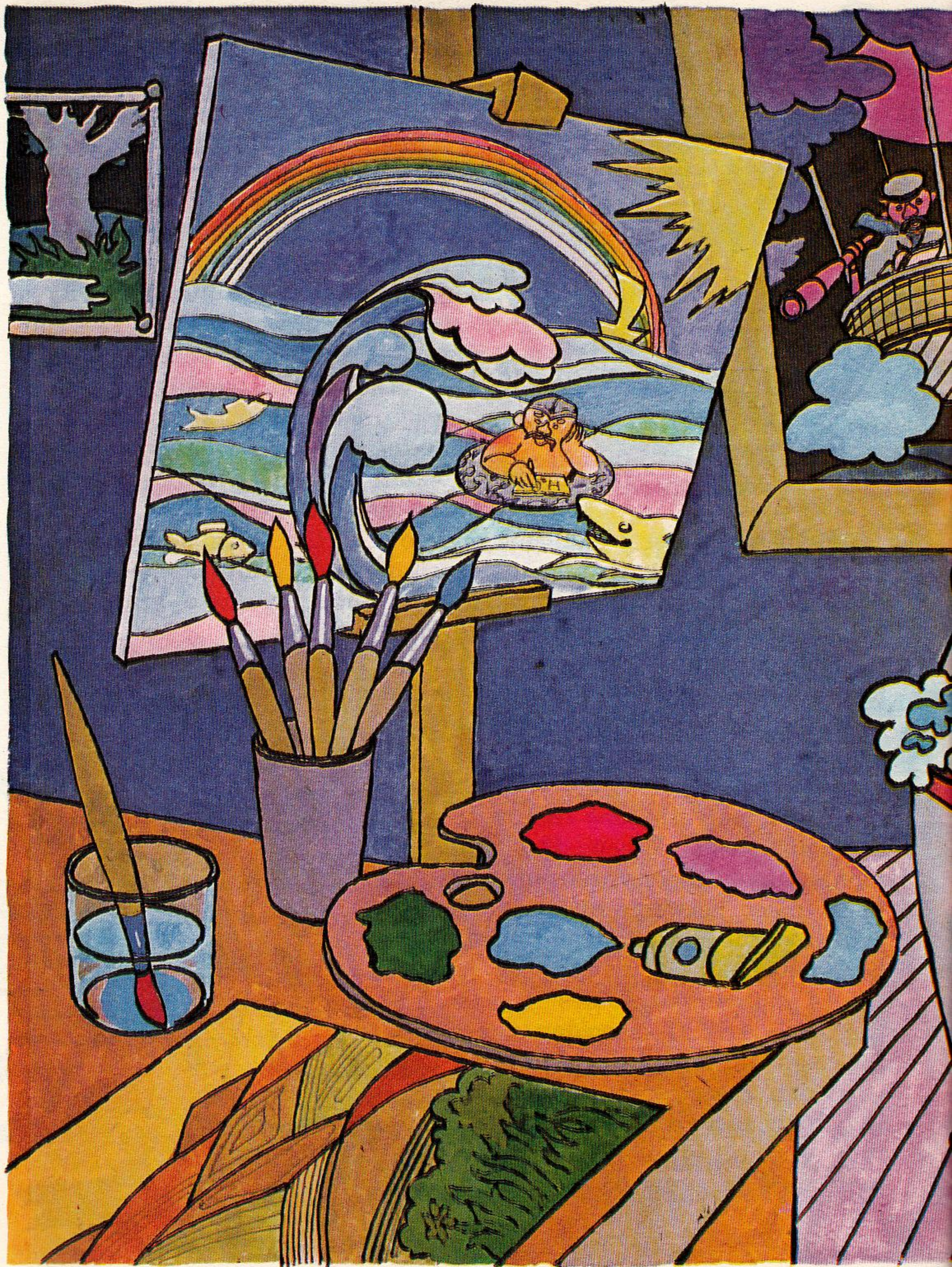
And what would happen if you made the tank out of a material which is not wetted by water, polyethylene, say? (And the tap too, of course.)

Then the water would not come out of the tank at all! Even if you turned the tap full on, not a single drop would come out of it! After all on earth water flows down out of a tap due to gravity, but in space water is weightless and does not fall.

How can the water be got out of the tank? It can be pressed out, for example, by a plunger. Or the sides of the tank can be made soft, elastic, and the water can be squeezed out like toothpaste from a tube. Instead of a tap, you can use a soft polyethylene tube with a mouthpiece. When the cosmonaut feels thirsty, he puts the mouthpiece between his lips and squeezes the water straight into his mouth.

As you can see, to design even the most trivial everyday items for cosmonauts, you have to know in which cases water is wet and in which cases it isn't, and take into account the behaviour of molecules in general.







38 HOW TO MAKE WATER WET FOR EVERYTHING

Why is water wet for some substances and not for others? Why do water molecules combine more strongly with the molecules of some substances than with one another and more weakly with the molecules of other substances?

When scientists first began to study the differences between substances wetted by water and substances not wetted by water, they discovered the following. The molecules of "water-loving" substances are electrical particles, just as water molecules are. You could put the minus and plus signs of torch batteries on them as well. That is why water molecules cling to them. Birds of a feather flock together, as the saying goes.

But what about ordinary, non-electrical molecules? In their case the same rule has been observed: molecules of the same kind, i.e., non-electrical molecules, also cling to those of the same kind.

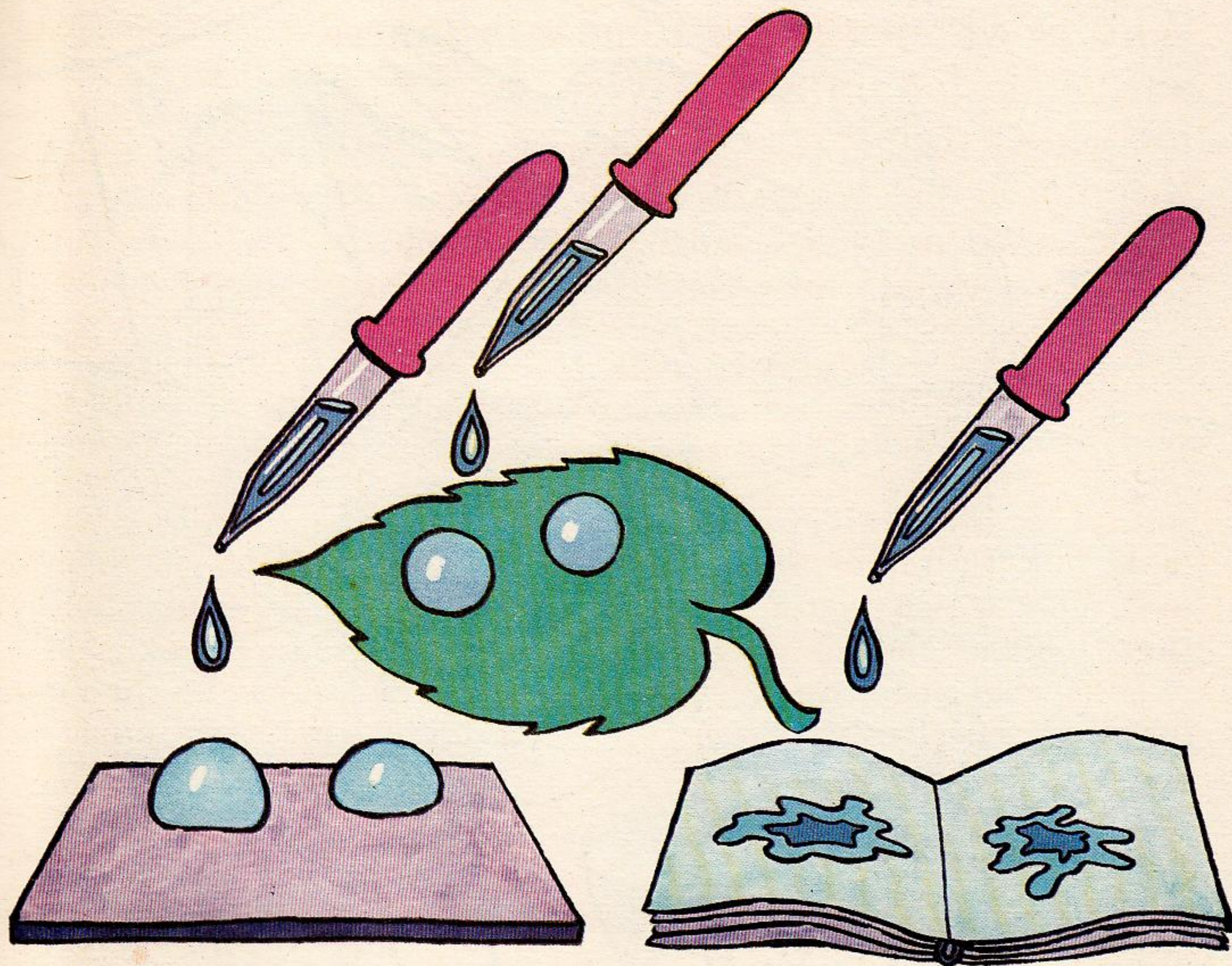
This is why paraffin, for example, which is not wetted by water, is easily wetted by fat.

But say you need to wet with water a substance with non-electrical molecules. Can you give the water wetting properties for these molecules too?

Yes, you can. But before explaining how this is done, I will tell you how they catch giant turtles in certain southern countries.

The shell of the sea turtle is smooth and slippery, making it difficult to catch. So the local inhabitants lower a special fish, called remora, with a line tied round its tail. This fish has suckers on its back and moves around by attaching these suckers to something, a shark, a whale or a turtle. So the fish immediately sticks to the turtle shell and the turtle is hauled up into the boat.

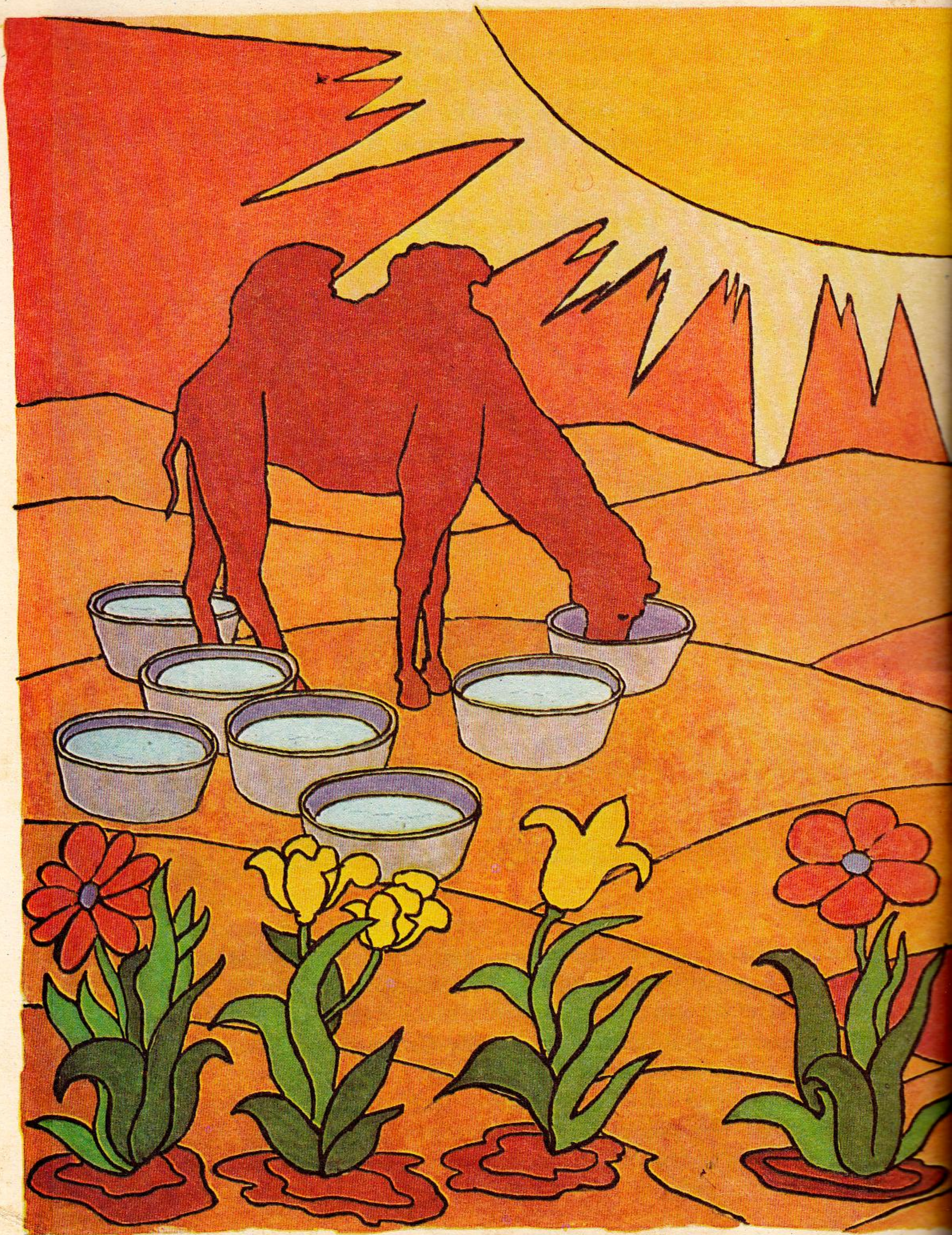
There exists a molecule like this fish with a line tied to its tail. One end of the molecule is electrical, the other is not. A water molecule can stick firmly to the electrical end, and the non-electrical end will stick to a molecule to which a water molecule



cannot adhere, a fat molecule, for example, and pull it off. Off what? Off anything. A plate, for example, or skin.

Say your hands are greasy. Water alone will not get them clean. So you must take some "sucking" molecules. I mean molecules of ordinary soap, of course.

Many people think that soap and water wash because of the foam. As if the foam bubbles catch the particles of dirt and the water washes them off. Now you can see that the foam has nothing





42 to do with it. There are even types of soap which do not produce foam (castor soap, for example), yet they wash as well as the ordinary ones.

So, when soap molecules are in water they make water wet for substances which are usually "afraid" of water. But how do other molecules affect water?

Drip some ordinary water from a pipette and some sweet water next to it and note the shape of the drops (only bear in mind that the surface on which you let these drops fall must be clean).

If the surface is not wetted at all, the drops will be globe-shaped, like dew on leaves or blades of grass. If the surface is easily wetted, however, the drops will spread out and cover it in a thin layer. And if it is wetted, but not very easily, the shape of the drops will show in which of them the water is "wetter".

In this way you will be able to study how not only sugar, but also salt, citric acid, soda and glycerine, in short any substance you can get hold of, provided that it is soluble in water, affects the wetting properties of water.

HOW SUBSTANCES WITHOUT MOLECULES ARE CONSTRUCTED

At the beginning of this little book we compared atoms to letters of the alphabet. You found out that atoms can combine in molecules just as easily as letters in words, and you were introduced to substances composed of molecules.

There are many substances which are constructed differently, i.e., which do not have molecules.

Such, for instance, is the construction of graphite. Its flakes are made up of carbon atoms built into a net.

The hardest substance in the world, diamond, is also "composed" of carbon atoms which are tightly bound together. But unlike those in graphite, not in a "net", but in a "lattice". It is impossible to detect the individual molecules in this atomic "lattice".

The atoms of metals are also combined in a "lattice". They do not have molecules either.

Do the following experiment. Dissolve some salt in water, pour the salty water into a dish and wait for it to evaporate. On the dish you will see lots of tiny transparent cubes. These are salt crystals.

Here too the lattice is made of atoms, and there is not a single molecule. Unlike diamond and metals, however, salt crystals are composed of two different sorts of atoms, sodium and chlorine.

Sodium is a silvery metal which is very light, lighter than water! Chlorine is a heavy yellowish-green gas with a strong smell and highly poisonous. But the sodium and chlorine atoms have combined in a crystal lattice to produce a substance without smell or colour, quite unlike both sodium and chlorine!

Finally, there are also atoms which refuse to combine with anyone, with themselves or "alien" atoms. The gases composed of these unsociable atoms are called monoatomic gases. But each of them has its own name, helium, neon, argon, krypton, xenon, and radon. All these gases are present in the air, but in very small quantities.

So you see how diverse is the world of substances around us.

If you get interested in this invisible movement of substances which is taking place around us every second and want to know more about them, you can always turn to your teacher for assistance, read the books he or she recommends and, most interesting of all, do your own experiments. Who knows, perhaps you too will discover substances with completely new and unusual properties.

Good luck!

REQUEST TO READERS

Raduga Publishers would be glad to have your opinion of this book, its translation and design and any suggestions you may have for future publications.

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